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A REVIEW OF THE INSECTICIDAL USES OF ROTENONE AND ROTENOIDS FROM DERRIS, LONCHOCARPUS (CUBE AND TIMBO), TEPHROSIA, AND RELATED PLANTS

PART II: THYSANOPTERA

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The assistance of specialists in the Division of Insect Identification of the Bureau, in classifying the insects mentioned herein as to order and family, is greatly appreciated.

INTRODUCTION

This is the second in a series of papers designed to review all available information on the insecticidal uses of rotenone and the rotenoids. Part I reviewed tests with Derris, cube, timbo, Tephrosia, Mundulea, and their constituents on members of the orders Collembola, Orthoptera, Dermaptera, Odonata, Isoptera, Corrodentia, and Mallophaga. Apparently no tests with the rotenone plants on Thysanura, Ephemeroptera, or Plecoptera have been recorded. Part II, the present paper, reviews the tests that have been made on Thysanoptera.

THYSANOPTERA

Thripidae

Anaphothrips signipennis (Bagn.), the banana thrips

The Queensland Department of Agriculture and Stock (61) in 1933 reported that derris dusts were as good as nicotine dusts for the control of a light infestation of the banana thrips. Weekly treatments gave very good results.

Caldwell (9) in 1938 reported on the control of the banana rust thrips, Scirtothrips signipennis Bagn. [=Anaphothrips signipennis (Bagn.)], in Queensland. Three derris dusts were tested. They contained, respectively, (A) 15 percent of derris on a colloidal spreader, 1 percent of rotenone, and 2.7 percent of ether extractives; (B) 3.6 percent of ether extractives; and (C) 2 percent of rotenone, 0.1 percent of pyrethrins, and 39 percent of sulfur. A mixture of 40 pounds of dust A and 3 pounds of pyrethrum powder was also tested but proved in no way superior to the nicotine dusts and was subsequently discarded. The bunches were dusted with small hand dusters. Weekly treatments with nicotine dusts throughout the life of the bunch gave uniformly good results in all experimental plots; fortnightly treatments also gave a fair degree of control, though appreciably less than the more frequent applications. Derris dusts applied at weekly or fortnightly intervals gave results not obviously worse than those from the nicotine dusts. Observations on their toxicity to S. signipennis, however, indicated an undesirable variation from sample to sample.

The rapid but ephemeral action of the nicotine dusts, as compared with the slower but more prolonged effects of derris dusts, was fully appreciated; however, frequent and heavy rains exert a marked cleansing effect on bunches and may largely nullify any benefits to be derived from the more lasting toxicity of derris dusts. In fact, in the event of rain shortly after dusting, the value of the treatment might be negligible. On the other hand, the almost instantaneous effect of nicotine on the thrips must be an important factor in effecting control in showery weather. There was no evidence that the purely mechanical effect of the dust cover was of any practical service in the control of rust.

Bregmatothrips iridis Watson, the iris thrips

Smith and Utter (70) in 1937 reported tests to control B. iridis. During the preflowering season of 1936 derris was applied as a spray (0.025 percent of rotenone in diluted spray) with sulfonated castor oil at 1:400, six treatments being made at approximately weekly intervals beginning May 15 and ending June 16. Tests with the derris-powder spray and with nicotine fumigation were made in 1937 during the preflowering period and again after the flowers had matured. On the basis of the 2 years' tests both the derris-powder spray and the fumigation with nicotine were very effective as controls. In both seasons the plants with derris had a much healthier appearance than did those in any plot treated with the other materials, not being injured by either thrips or insecticide. As might be expected, better control of the thrips was obtained on the younger, less dense foliage during May and June than on the very heavy foliage that develops after flowering.

Diarthrothrips coffeae Will., a coffee thrips

In the fourth annual report (10) of the Coffee Research and Experimental Station, Lyamungu, Moshi, of the Department of Agriculture, Tanganyika, it was stated that a spray of Derrisol[2/] in water or in bordeaux mixture (1:500) is effective, and that it is cheaper than nicotine sulfate.

Frankliniella cephalica (Crawf.)

The Florida Agricultural Experiment Station (23) in 1927 reported that against a heavy infestation of F. tritici bispinosa Morgan [=F. cephalica (Crawf.)] on strawberry blossoms, Derrisol 1:800 was an almost complete failure, only about 10 percent of the insects being killed. Nicotine sulfate spray 1:800 killed nearly 90 percent.

Frankliniella fusca (Hinds), the tobacco thrips

See also under Sericothrips variabilis (Beach).

Folsom, of the Division of Cotton Insect Investigations, in 1934, in an unpublished manuscript, reported on the control of thrips on seedling cotton at Tallulah, La. The damage was done almost entirely by nymphs of Frankliniella tritici (Fitch), but two adults of F. fusca were also found. Tests were made on cotton, using derris (4 percent rotenone) and a nicotine-lime mixture of originally 3 percent of nicotine. Three series of tests were made in different parts of the field. Under favorable conditions both derris and nicotine mixtures gave almost 100-percent kill. The number of thrips present was too small to show whether derris or nicotine mixture was the more effective.

2/ The compositions of all proprietary products mentioned in this paper are shown in the list on page 42.

The South Carolina Agricultural Experiment Station (71) in its 1935 annual report stated that tests of dusts consisting of sulfur alone or mixed with nicotine, derris, and other materials, against F. fusca and F. tritici on cotton were not encouraging.

Gaines in 1937 reported in manuscript that he had tested a derris-clay dust (1.15 percent rotenone) for the control of three species of thrips, F. fusca, F. tritici, and S. variabilis, on cotton at Tallulah, La. There was no significant difference between treated and untreated plants in the average number of bolls per plant or average percentage of plants showing injury.

Morrill and LaCroix (44) in 1937 reported that cube as a spray was tested against F. fusca on tobacco. The cube powder (4 percent rotenone) was tried at 6 pounds and also at 12 pounds per 100 gallons plus sulfonated phenylphenol at 1:400 as a spreader. The sprays were applied at the rate of 50 gallons per acre. None of the materials (including nicotine, pyrethrum, and lauryl thiocyanate) proved satisfactory. Several growers have stated that they were of the opinion that the dusting with proprietary cube-root powders, when the plants were wet with dew, had a controlling effect on the thrips population.

Morrill and LaCroix (45) in 1938 reported tests of insecticides made during 1937 at the Windsor, Conn., tobacco substation. The following rotenone products were tried against the tobacco thrips: (1) A spray made of cube-root powder containing 1 percent of rotenone, 24 pounds to 100 gallons of water mixed with a spreader (sulfonated phenylphenol) at the rate of 1:400; and (2) a dust made from cube-root powder containing 1 percent of rotenone and applied at the rate of 12 pounds per acre, using the same spreader as in (1) at the rate of 1:200. Neither of these tests produced conclusive results. The best plant protection was provided by the application of the 1 percent rotenone dust containing the spreader at the rate of 1:200. The spray gave the next highest degree of protection. The degree of plant protection was determined by making counts of live thrips at 4-day intervals on five plants in each of the 1/20-acre experimental plots. The problem of controlling the thrips should receive further investigation.

Haude (30) in 1939 recommended spraying with cube or derris powder (4 percent rotenone), at the rate of 4 pounds per 100 gallons plus 0.5 to 1 percent of a wetter, for the control of the tobacco thrips.

Frankliniella minuta (Moult.)

F. moultoni Hood (syn., californica Moult.)

F. occidentalis (Perg.)

In California the term "flower thrips" is applied to these three species. As in the control work on the pear thrips, the rotenone-bearing insecticides and the pyrethrum mixtures have been used both as sprays and as dusts. On deciduous trees the sprays have succeeded somewhat

better than the dusts, probably because the dust does not readily penetrate the fruit clusters, and the leaves are not sufficiently developed to hold the dust in the trees. The rotenone-bearing mixtures (0.75 percent rotenone) have given fair results on peaches and plums, but have been less effective on this species than against the pear thrips. Such materials as derris and cube were used at the rate of 4 and 5 pounds to 100 gallons of water; the addition of 1 percent of light-medium oil apparently increases the penetration somewhat under the calyx and into fruit clusters.--Bailey (4) in 1938.

Frankliniella tritici (Fitch), the flower thrips

See under F. fusca (Hinds); also under Sericothrips variabilis (Beach).

Frankliniella sp.

Tinkham, extension entomologist of the University of Arizona, in his 1939 annual report (typewritten) stated that a spray of 4 pounds of Botano R plus 4 pounds of Botano N plus 1 gallon of molasses appeared to be useless for the control of the flower thrips, both adults and larvae, in apple and peach orchards and on strawberries. Tests were also made with Botano R plus one of the following: Summer oil; molasses; whale-oil soap; both whale-oil soap and Botano N.

Heliothrips haemorrhoidalis (Bouché), the greenhouse thrips

Metcalf and Flint (43) in 1928 recommended derris sprays for the control of the greenhouse thrips.

Heliothrips sp.

According to a letter dated May 18, 1938, from the Etablissements Rotenia, of 19 Rue Valkenburg Straat, Antwerp, Belgium, to R. C. Roark, this company makes an unnamed product which contains 12 percent of powdered Lonchocarpus nicou root (of 6 percent rotenone content) and 88 percent of talcum. Heliothrips on azalea are killed by this product.

Hercinothrips femoralis (Reut.), a sugar beet thrips

De Bussy, Van der Laan, and Diakonoff (7) in 1936 reported that Heliothrips femoralis [=Hercinothrips femoralis (Reut.)] was controlled by a dust containing 2 percent of rotenone and 5 percent of ether extract.

The North Central States Entomologists (50), meeting at Columbus, Ohio, on March 3-4, 1938, discussed the control of certain insects by the use of cube and derris. C. R. Neiswander stated that rotenone preparations have given good control of thrips, especially Heliothrips femoralis. When the problem is considered from the standpoint of economy and efficiency, as well as safety to plants, operators, and consumers, the rotenone sprays are considered most worthy of recommendation. Ground derris root of 4 percent rotenone content, used at the rate of 3 or 4 pounds to 100 gallons of water, has given fairly satisfactory results when used with a satisfactory wetting agent, such as Grasselli Spreader-Sticker.

In connection with this discussion, N. F. Howard remarked that increased toxicity of ground derris root was obtained by C. A. Weigel by the use of sulfated castor oil.

Bailey (4) in 1938 wrote that for such slow-moving types of thrips as Hercothrips femoralis (Reut.) [=Hercinothrips femoralis (Reut.), according to Crawford] the rotenone-bearing materials (0.75 to 1.0 percent strength) will also give satisfactory results under greenhouse conditions.

Hercothrips fasciatus (Perg.), the bean thrips

Excellent control was obtained on pears with a spray of 1 percent of summer oil and 5 pounds of derris (0.75 percent rotenone) per 100 gallons of water. Only one application was necessary.--Bailey (4) in 1938. Cube dust containing 0.75 percent of rotenone has been found effective in California.--Haude (30) in 1939.

Isoneurothrips parvispinus Karny, a tobacco thrips

The Proefstation voor Vorstenlandsche Tabak (59) in 1936 reported that fumigation with carbon disulfide was more effective than spraying or dusting with rotenone or derris for the control of Thrips (Isoneurothrips) parvispinus in greenhouses used for the cultivation of tobacco seedlings.

The same station (60) in 1939 reported that contradictory results had been obtained by planters in Java using derris against I. parvispinus on tobacco, owing to incorrect spraying and the poor quality of the insecticide. In investigations a rapid polarimetric method was adopted to determine the rotenone content of derris powders, and the results obtained agreed fairly well with those of biological tests. A satisfactory spray was prepared by adding 2 parts by volume of neutral coconut oil or peanut oil to 8 parts of a benzene extract of powdered derris containing from 10 to 12 percent of rotenone. This was diluted for use and gave from 98- to 100-percent mortality of the thrips. The addition of the oil served mainly to reduce the risk of scorching.

Scirtothrips aurantii Faure, a citrus thrips in South Africa

Andries (3) in 1932 recommended Derrisol at 1:600 or 1:800 for the control of S. aurantii.

Scirtothrips citri (Moult.), the citrus thrips

McGregor (38) in 1936 reported the results of tests of dusts against S. citri on navel orange trees in California. In these orchard tests the materials were applied on a commercial scale with the improved, powerful dusters developed for use on citrus. The plats usually were 30 trees long by 8 trees wide, and, with the exception of two orchards, the dusts were applied according to the generally adopted commercial schedule, as follows: First application, 90 pounds per acre; second application, 67 pounds per acre; third application, 45 pounds per acre; a total of 202 pounds per acre. For any given orchard series the dosage was practically identical for all dusts.

At Redlands, Calif., a dust of 6.67 parts of powdered derris and 93.33 parts of talc (rotenone content of mixture, 0.35 percent) permitted 35 percent of the fruit to be damaged by thrips, as compared with 56.5 and 72 percent in the two checks and only 0.3 percent when 400-mesh sulfur dust alone was used.

At Rialto, Calif., the use of the same derris dust resulted in 6.5 percent of the fruit being damaged by thrips, as compared with 31 and 48.3 percent in the two checks. Four-hundred-mesh sulfur gave 100-percent control. In a grove at Redlands, Calif., a dust consisting of 10 parts of derris dust, 50 parts of sulfur dust, and 40 parts of talc (rotenone content of mixture 0.5 percent) permitted 2.7-percent damage, as compared with 68 percent in the check and 0.5 percent when 325-mesh sulfur alone was used.

McGregor concluded that, although powdered derris and talc in two orchards gave indicated reductions of thrips damage amounting, respectively, to 45 and 84 percent, such results are not promising. A dust combining rotenone 0.5 percent (in the form of derris dust) and sulfur dust 50 percent reduced thrips damage to the extent of 96 percent, but the effectiveness was attributable in large measure to the sulfur in the mixture. According to McGregor, dusts employing pyrethrum (0.19 percent pyrethrins and 44 percent sulfur) or rotenone (0.5 percent rotenone and 50 percent sulfur) have reduced the citrus thrips 95 and 96 percent, respectively. These materials, being somewhat higher priced than the dusting sulfur, are not in general use at present against this pest.--Bailey (4) in 1938.

Scirtothrips longipennis (Bagn.)

Andison (2) in 1938, reporting on S. longipennis and its control in greenhouses, stated that sprays of derris and soap gave good results.

Sericothrips variabilis (Beach)

The South Carolina Agricultural Experiment Station (72) in 1936 tested nine combinations of insecticides in triplicate on seedling cotton as a control for thrips. [About 75 percent of these thrips were S. variabilis but the flower thrips, the tobacco thrips, and the onion thrips were also present.] Only one application of each material was made. The following table shows the percentage of reduction in thrips population in each case. When the plants were practically mature in size, a count was made of injured stalks to determine any difference in protection given by the various materials used. The stalks were counted on one row out of each of the 6-row plots. Stalks considered as injured were those having two central stems instead of one.

Tests of insecticides for control of thrips at Pee Dee Experiment Station, S. C.

Application, May 13	Reduction of thrips	Stalks injured
	Percent	Percent
Rotenone, 15%,[1/] + sulfur, 42.5%, + tobacco dust, 42.5%	65.56	50.52
Check	47.62	55.71
Paris green, 10%, + sulfur, 90.0%	100.00	39.46

1/ This probably means 15 percent of derris or cube containing 4 or 5 percent of rotenone.

Taeniothrips inconsequens (Uzel), the pear thrips

Fotherbridge and Thomas (58) in December 1937 recommended the following spray for the control of the plum sawfly, when the fruit-tree red spider or the plum thrips, T. inconsequens, are also troublesome: Mineral-oil emulsion, 3-1/5 pints; derris, 12 ounces; and water, 40 imperial gallons.

Bailey (4) in 1938 wrote as follows:

> During the last important epidemic of the pear thrips (1930-34) in California a demand for more effective and cheaper control was made. Of the newer materials the rotenone-bearing sprays and dusts employing derris and cube have been the most satisfactory, used at the rate of 4 to 6 pounds to 100 gallons of water. Slightly better results have sometimes been indicated with the addition of 1 percent of light-medium oil. Also, stabilized pyrethrum extracts, 3/4 to 1 pint to 100 gallons of water, with a suitable spreader, show considerable promise but as yet have not been widely used. Certain organic chemicals now employed against other insect pests need careful testing for the pear thrips. The rotenone-bearing sprays have been successfully combined with the arsenate of lead calyx spray on pears. Rotenone-bearing dusts (0.75 percent rotenone), particularly for the larvae, when used at the rate of not less than 30 pounds per acre on prunes, have given excellent control. Though this experimental work is still incomplete as to the best mixtures and amounts, such materials may be expected to replace the older contact insecticides; they have definitely continued to kill the larvae up to 5 days after application. Before full bloom (for the adult thrips) sprays or dusts are often ineffective. If, however, the emergence has taken place over a very short period and the buds have opened rapidly, kills may be very satisfactory.

Bailey (5) in May 1939 reported that rotenone (probably derris) at the rate of 5 pounds per 100 gallons has been found to be one of the best controls for T. inconsequens in northern California. Rotenone should not be mixed with lime sulfur, because they are not compatible.

Taeniothrips simplex (Morison), the gladiolus thrips

Hamilton (29) in 1933 made field tests with derris, cube, and pyrethrum against the gladiolus thrips. A number of kinds of inert dusts were tested as diluents. Most of these were light and fluffy and dusted beautifully, but unfortunately did not adhere to gladiolus or other foliage. The best control in the greenhouse was obtained by dusting once with talc containing 0.5 percent of rotenone. Derrisol; Derrisol plus 2 percent of wheat flour; Derrisol plus flour plus lead arsenate; Derrisol plus dry bordeaux plus lead arsenate; and various rotenone dusts, including the proprietary product N O C, were also tested in the greenhouse. Most of the liquid sprays containing nicotine, pyrethrum, or rotenone were not very effective in reducing the thrips population. The dusts containing rotenone, were somewhat more effective than were the pyrethrum dusts.

Richardson and Nelson (65) in 1933 reported on the field control of the gladiolus thrips. The following derris preparation was tried: Derris extract (acetone extract containing 2.3 gm. of rotenone plus extractives, per 100 cc.) 2 fluid ounces; potassium-coconut oil soap (40-percent concentrate) 9 fluid ounces; and water 6 gallons. This contained 0.006 gm. of rotenone per 100 cc., or 1 gm. per 17,000 cc. This derris preparation was not so effective as white oil-nicotine (nicotine 0.04 percent, or 1 gm. per 2,500 cc.) but was more effective than pyrethrum soap (pyrethrins = 0.014 percent) or sulfur dust. Only the plants sprayed with nicotine sulfate-soap were injured. A mixture of paris green 1 ounce, brown sugar 2 pounds, and water 3 gallons was the most effective of the insecticides tested.

Richardson (62) in 1933 said that in preparing derris-extract sprays with commercial concentrated acetone extracts of derris (containing from 2.3 to 5 gm. of rotenone per 100 cc. with a total of 16 to 18 percent of derris extractives) large quantities of precipitates were formed when 1 part of the extract was added to 250 to 500 or more parts of water, a soap solution, or solutions of various other wetting agents. Such precipitates are apt to clog spray nozzles and may contain active constituents which might be less effective in such a poorly dispersed state. It was found that coagulation could be overcome and a milky dispersion of the extractives obtained by diluting the extract with acetone (1:1) before adding it to water or to aqueous solutions of various wetting agents. Residues from sprays so prepared retained their toxicity to thrips much longer when sulfonated castor oil (1:400) was used as the wetting agent instead of potassium-coconut-oil soap (1:300). Sulfonated castor oil (turkey-red oil) at 1:400 wet effectively the foliage of various plants, including gladiolus, rose, and onion.

Weigel and Smith (89) in 1933 reported on the status of the gladiolus thrips in the United States. Information gleaned from correspondence with growers indicates that no entirely successful control of this thrips on the growing crop was obtained by the methods they used, including derris sprays and dusts.

McDaniel (36, 37) in 1933 reported trials to control the gladiolus thrips in Michigan. The following spray gave the best commercial results in 1932: 3-1/2 ounces of lead arsenate, 4 ounces of Derrisol, 1 pound of glue, and 10 gallons of water. This was applied eight times at 48-hour intervals. Other materials tried were nicotine sulfate with soap, nicotine sulfate with lime sulfur, and Evergreen (pyrethrum preparation) with lead arsenate.

The Massachusetts Agricultural Experiment Station (40) in 1934 reported results of tests of insecticides against various insects. Against the gladiolus thrips, Derrisol 1:600, pyrethrum spray 1:600, and a combination nicotine sulfate 1:800 with Penetrol 0.5 percent, proved to be about equal in value but were slightly less effective than the paris green-molasses spray. The same station (41) in 1935 referred to Red Arrow as a pyrethrum-rotenone spray and reported that at 1:200 it killed 90 percent of adult gladiolus thrips in 24 hours and at 1:400 plus Dipest 1:400 it killed 100 percent of the thrips. Cubor, 2 pounds to 100 gallons, killed 60 percent of adult gladiolus thrips and at 4 pounds to 100 gallons it killed 100 percent. Kubatox at 1:400 killed 75 percent of adult gladiolus thrips and at 1:200 it killed 100 percent.

The Florida Agricultural Experiment Station (24) in 1934 stated that in a series of tests a rotenone preparation gave better control of the gladiolus thrips than did the poisoned sirup (paris green in sirup) usually recommended for this purpose.

Richardson (63) in 1934 compared derris, nicotine, paris green, and other poisons mixed with molasses for the control of the gladiolus thrips. An acetone extract of derris containing 5.7 gm. of rotenone and 18.1 gm. of total extractives per 100 cc. was used. At 1:250 (equivalent to 0.228 gm. rotenone and 0.724 gm. total extractives per liter of 5-percent-molasses solution) the deposit left by this spray killed all nymphs hatching over the 7-day period after the application. Three weeks after spraying, the residue killed 50 percent of the thrips. The author concluded that derris extract with molasses solution left a very toxic deposit and was effective in control tests in the greenhouse. The residues of derris extract, alone or in combination with soap or sulfonated castor oil, were toxic shortly after the application, but lost toxicity much faster (especially the soap spray) than derris-molasses residue when exposed to direct or to glass-filtered sunlight. The derris-molasses deposit was easily washed off by rain and under field conditions was attacked by a fungus.

De Bussy, Van der Laan, and Jacobi (8) in 1935 reported that laboratory tests showed thrips to be very sensitive to rotenone, but thrips on gladiolus could not be controlled by spraying or dusting with derris because the toxic agent did not come in contact with the insects.

The Florida Agricultural Experiment Station (25) in 1936 reported that of all the insecticides tried against the gladiolus thrips, a commercial rotenone dust gave the best results.

The Massachusetts Agricultural Experiment Station (42) in 1937 reported that for the control of the gladiolus thrips, Derrisol, Kubatox, and Lethane 420 were used as spray materials at dilutions of 1:600. Four applications were made at weekly intervals when the infestation began to develop, and the comparative effectiveness was determined by the amount of injury to the plants and blossoms. The derris sprays were superior to the thiocyanate compound.

The New South Wales Department of Agriculture (46) in 1937 reported that for field infestations of the gladiolus thrips, a dust made by mixing 1 pound of derris with 8 pounds of kaolin or talc should be applied weekly, beginning as soon as the first silvering of the foliage is noticed.

Other materials such as the rotenone-bearing materials (derris, cube, and the like), thiocyanate, and pyrethrum extracts, are used by some growers with good results. As yet there are insufficient data on the newer organic insecticides to permit any recommendations for their use on the gladiolus thrips.--Bailey (4) in 1938.

Smith and Johnson (69) in January 1939 reported the results of tests in 1938 for the control of the gladiolus thrips. Sprays containing derris and peanut oil transformed the normal green surface of the gladiolus foliage to an oily, dust-covered condition, accompanied by a yellowing. The plants sprayed with this combination were also retarded for more than a week in the development of their flower spikes. The plants treated with a derris-powder spray containing 0.02 percent of rotenone were more adversely affected than those treated with a derris-powder spray containing 0.015 percent of rotenone, even though peanut oil was used at a concentration of 1 percent in both these sprays. In addition to stunting the growth and delaying the flowering of the gladiolus, the sprays containing derris and peanut oil gave practically no control of the gladiolus thrips. A spray composed of derris powder containing 0.015 percent of rotenone, with varnish as a sticker, gave partial control of the thrips. A spray containing 4 pounds of tartar emetic plus 8 pounds of brown sugar per 100 gallons gave the best results.

Taeniothrips xanthocerus (Hood)

Worsley (94) in 1934 expressed the belief that extracts of Tephrosia vogelii should eventually replace nicotine as a contact spray against aphids and thrips, probably (Physothrips) Taeniothrips xanthocerus Hood, and similar soft-bodied insects in East Africa. He reported that an aqueous extract of the leaf made with boiling water is as toxic as an alcoholic extract; made with cold water it is about 50 percent less toxic. With the seeds, boiling water gives an extract only half as toxic as an alcoholic extract, and cold water almost fails to extract any toxic principle; this difference is no doubt due to the presence of 12 percent of fixed oil in the seed. Boiling for 60 minutes is not more effective than for 30 minutes. An extract of the leaves made with boiling water and using 0.5 percent of soft soap as a spreader has been used successfully against thrips on some experimental coffee trees in Amani.

Thrips fuscipennis Haliday, a rose thrips

Orchard, Read, and Speyer (54) of the Experimental and Research Station, Cheshunt, England, in 1938 reported that T. fuscipennis was not controlled by sprays containing derris extract (4 ounces rotenone per 100 imperial gallons), or by dusts containing ground derris. This same station (21) in 1939 reported that derris dust (2.5 percent rotenone) acted slowly on this insect, 3 days elapsing before an appreciable percentage was killed. Derris spray, consisting of 2 pounds of powder and 10 pounds of soft soap to 100 imperial gallons, had a deterrent action for 4 days but was slow and uncertain in its killing action.

Thrips imaginis Bagn., an apple thrips

Wheeler (90) in 1934 reported the results of tests of dusts against T. imaginis in Australia. Tests with derris and pyrethrum powders showed that rotenone was not so effective as an equivalent amount of pyrethrin I. A fresh sample of a dust containing derris, barium fluosilicate, and sulfur killed 99 percent of the thrips, whereas after 25 hours' exposure to bright sunlight in a thin layer it killed only 65 percent. During the exposure the characteristic odor of derris root was lost and the rotenone content (determined by Jones' method after removing the sulfur) dropped from 1.5 to 0.9 percent.

J. Davidson (16) in 1935 reported the results of tests against apple thrips in Australia. The following dust gave promising results in small-scale tests: Kaolin or talc, 80 or 70 percent; derris powder (3.5 percent rotenone), 15 or 20 percent; and pyrethrum powder (0.2 percent pyrethrins), 5 or 10 percent. Derris and pyrethrum repel thrips, but gradually lose their toxic properties on exposure to air and sunlight. In orchard practice it is not expected that the dust will be effective for more than 2 days after application, therefore further applications will be required as necessary. Dusts having the higher concentrations of derris and pyrethrum will be more efficient, but more costly. Where derris cannot be obtained, a pyrethrum dust may be used, but its efficiency will be considerably less than that of a dust containing both derris and pyrethrum.

For growers who desire to use a spray, the following formula is suggested: Finely crushed derris root 2 pounds, soap 5 pounds, and water 100 imperial gallons. This spray can be made up by the grower. It must be prepared fresh, immediately before use, because it deteriorates on standing. Oil emulsions containing derris and pyrethrum appear to be more promising than aqueous sprays.

Thrips lini Lad.

Ovinge (55) in 1938 described spraying experiments for controlling T. lini on flax in Holland. Satisfactory results were obtained with derris plus soap as a spreader. The derris powder contained 5 percent of rotenone and was used at the rate of 4 kg. per 1,000 liters of water. Two or three applications were made. The best time for spraying is in May. Ovinge's work is referred to by Spoon (73).

Thrips nigropilosus Uzel, the chrysanthemum thrips

Richardson (63) in 1934 tested a molasses-derris-extract spray (0.228 gm. rotenone and 0.724 gm. total derris extractives per liter of 5-percent-molasses solution) on thrips. Under greenhouse conditions it gave commercial control of T. nigropilosus on cineraria.

Thrips tabaci Lind., the onion thrips

See also under Sericothrips variabilis (Beach).

The Ohio Agricultural Experiment Station (52) in 1928 reported that Derrisol at 1:400 gave 97 percent control of the onion thrips in greenhouses. W. M. Davidson (17) in 1930 reported the following results with rotenone against adults and nymphs of the onion thrips on bean plants:

Concentration		Net mortality
Rotenone (gm.)	Water (cc.)	Percent
1	20,000	94.2
1	30,000	69.3
1	100,000	0.0

A dust consisting of 2 parts of rotenone and 98 parts of diatomaceous earth killed 65.5 percent of the nymphs.

W. M. Davidson (18), in comparing the insecticidal value of rotenone, deguelin, and toxicarol, used T. tabaci as one of the test insects. Deguelin at 1:10,000 killed more than 50 percent and toxicarol at 1:250 killed 12 percent.

Franssen and Van Heurn (26) in 1932 reported that an aqueous extract of derris was very effective against the onion thrips. This extract was prepared in the following way: Ten kg. of akar tuba (derris roots) were boiled for 3 hours in 20 liters of water, the liquid extract was then filtered off, and 50 gm. of green soap was added and finally diluted to 30 liters of solution. Tests were also made with Neoton.

The Massachusetts Agricultural Experiment Station (39) in 1933 reported the results of tests for the control of the onion thrips. Nicotine sulfate sprays gave the greatest reduction in number of thrips, and their action was more rapid than that of other products. Derrisol was somewhat slower in its initial action than nicotine but appeared to exert considerable residual effect, which retarded reinfestation except that caused by thrips migrating from adjoining fields.

The Illinois Agricultural Experiment Station (33) in 1933 reported that spraying with Derrisol at the rate of 1:800 plus Penetrol 1:200 resulted in a 24-percent increase in yield of onions. In laboratory tests onion thrips were killed with even more dilute solutions of these sprays, but such solutions do not give the best results when used in the field.

According to Penick and Company (57), manufacturers of Foliafume, (a pyrethrum-derris spray with spreader), this product at 1:400 killed 90 percent of the onion thrips after 48 hours.

Shropshire (67), at a meeting of the North Central States Entomologists at Purdue University in 1934, said that nicotine and derris preparations used as sprays in combination with suitable spreaders gave partial control of the onion thrips but were not practical for use under field conditions.

Richardson (63) in 1934 reported that an acetone extract of derris in molasses (0.228 gm. rotenone and 0.724 gm. total derris extractives per liter of 5-percent-molasses solution) was not effective against T. tabaci on onion. In greenhouse and small field tests derris extract with sulfonated castor oil was more promising for onion thrips control than was nicotine sulfate and soap.

Currie (15) in 1934 reported that near Watsonville, Calif., derris dust at 30 pounds per acre gave unusually good results against the onion thrips.

Turner and Friend (75) in 1934 reported on the control of the onion thrips in Connecticut. Sprays of nicotine sulfate (40 percent) 1:800, pyrethrum soap 1:600, and a proprietary rotenone solution 1:400, all with 0.5 percent of dry soap, reduced the population of the thrips but failed to prevent serious injury after the tops of the onions went down. There was little difference in the efficiency of the three materials. The pyrethrum and rotenone products were diluted according to the manufacturers' directions. In view of the difficulty in obtaining a satisfactory sprayer and the relatively poor protection afforded by use of contact materials, spraying onions to control the thrips does not seem advisable.

Huckett and Harvey (32) in 1935 reported that derris and cube spray and dust mixtures at strengths comparable to those used to control green worms on cabbage and cauliflower have shown promising results when applied for the control of T. tabaci on cauliflower seedlings.

Walker and Anderson (84) in 1935 reported that the Virginia Truck Experiment Station derris dust containing 0.5 or 0.75 percent of rotenone appeared to give very good control of the onion thrips early in the season, but as soon as infestation became very severe on the check plats and on other crops, the thrips migrated in so fast that the derris dust failed to keep them under control on onions.

Richardson (64) in 1935 stated that sprays of derris powder (2.9 percent rotenone and 16.7 percent extractives) at a concentration of 0.25 percent by weight, plus sulfonated castor oil (1:400), killed the onion thrips on cucumber.

Howard, Mason, and Davidson (31) in 1935 reported that derris powder (5.5 percent rotenone) at the rate of 3 pounds per 100 gallons of water, plus 2 pounds of soap, was very effective in killing the onion thrips when sprayed at the rate of 400 gallons per acre.

Shropshire and Compton (68) in 1935 published recommendations for saving garden crops from insect injury. A nicotine-Penetrol or Derrisol-Penetrol spray of the proper dilution will kill thrips, T. tabaci, if they are hit with it. Investigations in Illinois showed that 1 ounce of nicotine sulfate or Derrisol and 4 ounces of Penetrol to 6 or 8 gallons of water made a fairly satisfactory spray but did not give complete control in extremely heavy infestations. A high-pressure sprayer is most suitable for the application of these sprays. The nozzles should be set so that the spray is driven into the center of the onion plants, where large numbers of thrips feed.

The Massachusetts Agricultural Experiment Station (41) in 1935 reported that Kubatox spray was nearly as effective as nicotine sulfate-soap spray for the control of the onion thrips. Rotenone dusts were inferior to the sprays.

Van der Laan (35) in 1936 included T. tabaci in a list of insects sensitive to derris.

De Bussy, Van der Laan, and Diakonoff (7) in 1936 reported that in Java T. tabaci was controlled by derris dusts or sprays.

The New York (Cornell) Agricultural Experiment Station (47) in 1936 reported that derris added to naphthalene dust was the only material that increased the efficiency of dusts previously recommended for use against the onion thrips.

The Colorado Agricultural Experiment Station (11) in 1936 reported that combinations of pyrethrum and rotenone sprays were tested against the onion thrips, but that the results did not justify the expense.

The Florida Agricultural Experiment Station (25) in 1936 reported tests against the onion thrips. On older celery, particularly that which had been prepared for blanching, nicotine and rotenone dusts gave better control than did the liquid nicotine or pyrethrum sprays, because it was so difficult to get sufficient penetration of the sprays through the covering of outer leaves.

The United States Department of Agriculture, Bureau of Entomology and Plant Quarantine (78), in 1936 reported that rotenone sprays containing wetting agents and spreaders gave encouraging results against the onion thrips in Puerto Rico.

Fenton (22) in 1936 compiled information on the use of sulfur in the control of truck-crop and cane-fruit insects and diseases. Unpublished reports from the Cornell University Agricultural Experiment Station are cited, which show that a dust made by adding 10 pounds of derris (4 percent rotenone) to 90 pounds of dusting sulfur was effective against the onion thrips.

Weigel and Nelson (86) in 1936 reported that in greenhouse tests at Beltsville, Md., sprays containing 0.0056 percent of rotenone and pyrethrum extract (1:10,000) with sulfonated castor oil added (1:300) as a spreader, and organic thiocyanate sprays diluted 1:300, and applied at 300 pounds' pressure by a specially devised greenhouse power sprayer, were effective in killing adults and nymphs of T. tabaci without injury to the treated cucumber plants in the greenhouse. The addition of pyrethrum extract to either the derris or cube powder sprays enhanced their efficiency against the thrips. An immediate effect was evident against both the adults and the nymphs. The cube powder plus the sulfonated castor oil was not so effective as a derris-powder spray, even though the rotenone content (0.0056 percent) of each was the same. No mildew appeared in any sprayed plots, whereas in the check plots it was consistently present, which may indicate some fungicidal action on the part of the sprays containing rotenone or organic thiocyanates.

Walker (83) in 1938 reported that the addition of Ultrawet to cube in sprays enhanced the control of the onion thrips. Four pounds of cube per 100 gallons plus 8 pounds of a mixture of sulfur and Ultrawet (16:1) gave a control of 56.4 percent, as compared with 31.4 percent for the same mixture without cube. Four pounds of cube plus 0.5 pound of Ultrawet per 100 gallons controlled 79.1 and 61.3 percent of the thrips in two tests.

The New York Agricultural Experiment Station at Cornell University (48) in 1937 reported that rotenone added to naphthalene-talc dust slightly increased the effectiveness of this treatment against the onion thrips. Rotenone dust undiluted was not satisfactory. Ground derris root and cube root as sources of rotenone in sprays controlled the immature stages but were not so effective against the adults. There were no noticeable differences in the effectiveness of these two sources of rotenone.

The Massachusetts Agricultural Experiment Station (42) in 1937 reported that for the control of the onion thrips the materials tested did not show to best advantage, because the infestation in the experimental plots was light, and none of them proved equal to the nicotine-soap combination in their immediate effects. The rotenone compounds, however, showed a very pronounced residual effect over a 7-day interval, as shown in the following table:

Treatment	Average thrips per plant 1 day after application	Average increase in thrips in 7-day interval
	Number	Number
Derris- - - - - - - - - - -	12.2	8
Niagron (contains rotenone)	17.9	7.7
Nicotine tannate- - - - - -	12.8	25.8
Oil-nicotine- - - - - - - -	17.1	2.9
Nicotine sulfate-soap - - -	3.9	17.4
Unsprayed - - - - - - - - -	22.8	18.4

The Puerto Rico Experiment Station (81) in 1937 published the results of insecticide tests against the onion thrips. Derris powder plus a commercial sticker and spreader gave the best results, increasing the yield of marketable onions 390 pounds over that of the check. Derris powder alone and also with sulfonated castor oil gave good results; however, to date derris has been too expensive to use on a commercial basis for the control of the onion thrips on the island.

Weigel and Nelson (87) in 1937 and again (88) in 1938 reported that in experiments against the common red spider and T. tabaci on greenhouse-grown tomato and cucumber plants, in which four sprays were applied at 4-day intervals, a derris spray having a rotenone content of 0.0056 percent was as effective as one with a 0.0112 percent rotenone content; the derris sprays used were superior to cube sprays of the same rotenone content, the difference being explainable on the basis of the total-extractives content, which was 18.6 percent for the derris and 12.3 percent for the cube; the addition of pyrethrum extract aided in killing the thrips but did not improve the effectiveness of the sprays against the red spider; sprays of the same rotenone content, containing sulfonated castor oil as a spreader, gave a better kill than when either alkylphenylbenzenesulfonic acid or rosin residue was used as a spreader. In a second series of experiments, using the same insecticides in four applications at weekly intervals, approximately the same results were obtained, except that on tomatoes the spray containing derris, pyrethrum, and alkylphenylbenzenesulfonic acid appeared to be as effective as the sulfonated castor oil sprays. None of the sprays except lauryl thiocyanate caused any permanent injury to either tomato or cucumber. These results are also given in the 1938 annual report of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture (80).

Turner and Walker (76, 77) in 1938 reported the results of tests of insecticides for the control of the onion thrips in Connecticut in 1933-37. In 1933 two applications of an extracted rotenone spray (Insect-Nox) plus 0.5 percent (by dry weight) of potash-coconut oil soap reduced the number of thrips but was slightly less effective than nicotine sulfate at 1:800. In 1936 cube dust (0.75 percent rotenone) and cube-sulfur dust containing 73 percent of sulfur were applied three times. There was no satisfactory control of thrips, and sulfur caused some injury to the onion tops. In 1937 cube, cube plus Ultrawet, cube plus Aresket, and cube plus sulfur plus Ultrawet were tried. The combination of pure ground cube root with a suitable spreader apparently protected onion plants from thrips if spraying was begun before the plants were heavily infested. In the one series applied after heavy infestation, the control was not so satisfactory as in the other tests. The addition of sulfur increased the mortality in hot weather, but apparently reduced it in cooler weather. As these tests were conducted on irrigated fields, drought did not seriously affect the yield of onions, but the irrigation had no marked effect on the number of thrips. Addition of a spreader to cube increased its effectiveness, and with a suitable spreader cube was more effective than nicotine sulfate.

Parks and Pierstorff (56) in 1938 recommended a rotenone spray for the control of thrips on onions.

Turner (74), and also the Connecticut Agricultural Experiment Station (12), in 1938 reported tests in Connecticut to control the onion thrips, which was more abundant and destructive during 1937 than for several years. Control tests were made on both set and seed onions in commercial fields. All sprays were applied with a spraying attachment on a garden tractor. In the first experiment pure ground cube root was used at the rate of 4 pounds in 100 gallons (1) with Ultrawet 1:800, (2) with Ultrawet 1:1600, (3) with Aresket 1:1600, and (4) with no spreader. These treatments were compared with nicotine sulfate 1:800 (1) with Ultrawet 1:1200 and (2) with Aresket 1:1600. Three treatments, June 16, June 25, and July 1, kept the thrips population low, but downy mildew killed the plants prematurely and there was no effect on yield. The tests showed, however, that cube was more effective than nicotine sulfate, that the addition of a spreader increased the effectiveness of cube, that Ultrawet was as effective as Aresket, and that Ultrawet at 1:1600 was more effective than at 1:800.

The second test was made on set onions infested with 500 thrips per plant. The materials were (1) pure ground cube root 4 pounds in 100 gallons of water, (2) cube plus Ultrawet 1:1600, (3) cube plus 12 pounds sulfur plus Ultrawet 1:1600, and (4) 16 pounds sulfur plus Ultrawet 1:1600. Two applications were made, on July 8 and 16, before downy mildew killed the onions. The cube-Ultrawet was the most effective. The addition of wettable sulfur increased the effectiveness in hot weather but reduced it in cool weather.

The third test was made on seed onions lightly infested when the first spray was applied. Dates of spraying were July 16, 23, and 30 and August 6. The materials were cube-Ultrawet and cube-sulfur-Ultrawet. The 4 applications of cube-Ultrawet kept the population low all season; final count, 24 per plant. The addition of sulfur did not increase the effectiveness. The yield of the sprayed onions exceeded that of the untreated plots by more than 100 bushels per acre.

Dunlap and Turner (19) in 1938 recommended cube, 4 pounds per 100 gallons plus a spreader, for the experimental control of thrips on onions. It should be applied every 10 days until the tops fall over.

Roark (66) in 1938 reviewed the work of Weigel and Nelson (86), who reported derris to be superior to cube when used against the onion thrips.

The Washington Agricultural Experiment Station (85) in 1938 reported the results of tests made to reduce onion thrips damage to carnation blossoms in the greenhouse. The following materials proved superior to paris green with brown sugar: Derris extract with different spreaders, ground derris root with Karaya gum and a wetting agent, pyrethrum extract with spreaders, nicotine sulfate with molasses, and tartar emetic with spreaders but not with brown sugar.

Jones (34) in 1939 recommended derris or cube for the control of the onion thrips.

Haude (30) in 1939, in a review of recommendations for the use of rotenone dusts and sprays, stated that dust is less effective than spray for the control of thrips on ornamentals, but against the onion thrips either a dust (0.75 percent rotenone plus 0.5 to 1 percent wetter) or a spray (4 pounds powder of 4 percent rotenone content plus 1/2 pound wetter per 100 gallons) may be used.

O'Kane (53) in 1939 reported that derris powder plus Ultrawet made an effective spray for the onion thrips.

Crosby, Chupp, and Leiby (14) in 1939 recommended rotenone dust as effective against the onion thrips on onions and cabbage. If the cabbage seedbed is infested by both the cabbage aphid and the thrips, a dust containing 0.75 percent of rotenone may be used. It is a good plan to apply the rotenone dust in the evening when the dew is falling, and not in the morning. A dust containing 0.5 percent of rotenone has proved satisfactory for use on bunching onions where fresh green tops bring a market preference. These dusts are most efficient when used at weekly intervals as the thrips appear on the plants.

Thripidae (unidentified species)

Winston (93) in 1926, in reviewing information on Derrisol for the benefit of Florida citrus growers, stated that it should be diluted to a 1:800 solution for use against thrips.

The Nyasaland Department of Agriculture (51) in 1927 reported that a solution of the green leaf of Tephrosia vogelii is a very efficient contact insecticide for thrips. The green leaf was used at the rate of 1 pound to 12 imperial gallons of water. It was crushed, soaked in a little water, squeezed, and strained through sacking, and the liquor made up to the desired quantity. It was found necessary to add a spreader because, although the solution by itself killed the thrips, it did not cover enough of the leaf surface when applied as a spray. Soap was the only material that could be obtained and, although this has killing powers in itself, it was possible to reduce the quantity of soap to a minimum, only 4 ounces of soap being used to 12 gallons of Tephrosia solution.

Corbett (13), entomologist for the Federated Malay States Department of Agriculture, in 1930 reported that tuba (derris) used at the rate of 10 pounds to 100 imperial gallons of water is a good insecticide for general use in the garden, as plants regularly sprayed will be kept comparatively free from thrips.

W. M. Davidson (17) in 1930 sprayed a suspension of rotenone in water upon nymphs of a species of Thrips on Plantago lanceolata in the field, with the following results: At a concentration of 1 gm. of rotenone to 10,000 cc. of water the net mortality was 100 percent. At 1:20,000 it was 39 percent.

Katakilla gave good results against thrips on rhododendrons at Boskoop, Holland, but was not entirely satisfactory for their control.--Wageningen Plantenziektenkundigen Dienst (82) in 1931.

Andries (3), in a handbook on the control of plant pests in southern Africa published in 1932 by Cooper, McDougall, and Robertson, manufacturers of Derrisol, recommended it for use against thrips. He also recommended Katakilla for the same purpose.

The East African Agricultural Research Station (20) in 1933 reported that extracts from Tephrosia vogelii are, weight for weight, more toxic than nicotine to thrips.

Gnadinger (23) in 1933 referred to unpublished work by Ginsburg, which indicates that rotenone is more toxic than the pyrethrins to thrips.

White (91) in 1933 reported that cabbage plants dusted with derris appear to be more thrifty and freer from thrips than those dusted with arsenicals, pyrethrum, or hellebore.

Barfoot (6) in 1935 stated that the cherry and pear growers of the Bay district of California used several tons of rotenone dusts for the control of slugs, aphids, and thrips. The greater part of this material was made by mixing cube root powder with kaolin, talc, whiting, or diatomaceous earth.

White (92) in 1936 wrote that derris dusts have indicated that they may aid in the control of thrips that infest cabbage and related crops, but in the 1937 revision of this processed circular (E-376) no mention is made of thrips.

According to advertising literature issued in 1937 by its American distributors, William Cooper and Nephews, Inc., Chicago, Ill., Derrisol contains 5 percent of derris resin and controls thrips. It is mostly used diluted with water 1:800.

An anonymous (1) writer in 1937 reported on the control of insects in the Netherlands in 1936. Pea thrips are little affected by derris powder.

The New York Agricultural Experiment Station (48) in 1937 reported that infestations of thrips and aphids in the cauliflower seedbed during July were effectively controlled by treatment with dusts of 0.5 and 0.33 percent rotenone content, the applications being made late in the evening under calm conditions, in anticipation of high relative humidity sometime during the night.

The Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, (79) in 1937 stated that cube dust did not control thrips on cotton.

Garman and Townsend (27) in 1938 reported that derris powder (4 percent rotenone) at 4 pounds per 100 gallons killed 100 percent of mite-feeding thrips.

INSECT INDEX

Composition of proprietary products mentioned in this paper

Product	Composition	Reference
Aresket	Sodium monosulfonate of monobutyl diphenyl	E-504
Botano R Spray	Cube and pyrethrum extractives	Manuscript
Cubor spray	Derris and pyrethrum extractives	Do.
Derrisol	Derris extractives, 5 percent	Do.
Foliafume	Derris and pyrethrum extractives	Do.
Insect Nox	A liquid product containing rotenone	Do.
Katakilla	Derris powder and soap	Do.
Kubatox	Derris or cube extractives	Do.
Neoton	Derris extract in fish oil	Do.
NOC	A dust containing 1.5 percent of rotenone	Do.
Penetrol	Sulfonated partly oxidized petroleum hydrocarbons	E-504
Red Arrow	Derris and pyrethrum extractives	Manuscript
Ultrawet	Water-soluble sodium sulfonate of petroleum hydrocarbons	E-504

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